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GIS AND HYDRODYNAMIC MODELING TO ANALYZE THE POTENTIAL OF FLASHFLOOD HAZARDS IN BT. KURANJI SUB-WATERSHED, WEST SUMATRA

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Abstract

Flash flood disaster has caused casualties and property losses due to excess rainfall which is rapidly occurred in a relatively short period. To analyze the potential of flash flood hazards in Bt. Kuranji Sub-watershed, West Sumatra Province, this study was conducted with hydrodynamic modeling using GIS which is consist of three analyses: (1) hydrological analyses such as the analyzes of peak-discharge, SCS-CN, and SCS Unit Hydrograph using HEC-HMS software ; (2) hydraulics analyses comprised of morphometry analyzes and flood modeling using HEC-RAS software; (3) the analyzes hazard potentials obtained from the depth and the velocity of the hydraulic analyzes result. Hydrological analyzes were performed in return periods of 2, 5, 10, 20, 50, and 100 years using 38 years of rain data which, the greatest flood potential is in the 100-year return period with Tp 3 hours and peak discharge 725 m3/s. The magnitude of flash flood discharge is the input data on the hydraulics analyses that found the area, velocity, depth, and flood water level. From the hydraulic analyses, flash floods during the 100-year period are known to have the potential to hit 20 urban villages with the high level of hazard is 8.36%, the moderate level is 52.76%, and the low level is 38.88%.

Keywords– GIS, Flashflood, Hydrodynamics Modelling.

1. Introduction

Floods occur due to high rainfall intensity accompanied by the presence of people and buildings in the wrong place such as in the floodplain area and followed by environmentally unfriendly activities (Wisner & Uitto, 2009). In general, the most dangerous type of flood is flashflood because it occurs quickly, causing losses and damage (Yin et.al., 2016). This happened in the Padang City area, which is an area with high rainfall intensity and there is a land conversion from a catchment area to a watertight area in the Kuranji watershed, thus triggering flash floods.

In July 2012, flash floods caused material losses in the form of damage to 6 road points, 6 bridges, irrigation units, places of worship, and 538 houses, of which 95 houses were seriously damaged (BNPB, 2012). Since 2012 flood disasters have become more frequent. Heavy rains on 12 September 2012 in Pauh Sub-district triggered landslides at three locations which resulted in Galodo (Banjir Flood) (Yogi, 2016). The flash flood disaster again damaged agricultural land, irrigation canals, and PDAM during the incident on March 21-22 2016. The flash flood was caused by high rainfall intensity and was accompanied by landslides in the upstream area. Therefore, it is necessary to study the potential danger of flashflood to reduce risk in the future. In addition, inventory and information on flood-prone river conditions, watershed capacity conditions, and watershed mapping are very important (PUSDALOPS-PB, 2016). Flash flood hazard analysis can provide an overview of potential disasters so that it can be used for identification and control of vulnerable aspects, and management to improve environmental quality and stability can also be pursued.

Many types of research on flooding and its relation to geo-information have been carried out, both on a sub-watershed scale and in merging several wider watersheds (Smith et al., 2014; Albano et al., 2015). Many studies use GIS to determine the causes and effects of flashflood as a disaster caused by the response of extreme rain in a watershed (Garambois et al., 2015), such flooding occurs in a very short time when the water level in the drainage canal reaches its peak within minutes to hours after a rainstorm, leaving very little time for early warning (Marchi et al., 2010).

The existence of the location, topography and climate of the region are capable of causing hydro-meteorological hazards, including the frequency of flashflood (Azmeri & Vadiya, 2016). Flash floods are mostly caused by high rainfall intensity on steep slopes and broken embankments, as well as inundation by river channel runoff due to river discharge that suddenly expands beyond the flow capacity, occurs quickly in the surrounding area, and flood waves carry the hard debris which is dangerous in the stream (Dip et al., 2012). Flash floods are limited as a flooding phenomenon that often occurs in watershed basins measuring less than 1000 Km2 with a short response time (Marchi et al., 2010). The smaller the basin size of a watershed, the frequency of flashflood becomes higher (Merz & Bloschl, 2008), and can cause saturation of the flow capacity on the watershed slope (Youssef & Pradhan, 2009).

Flash floods can cause physical damage, large economic losses, and health problems because they carry pathogenic bacteria into the urban environment, and cause the development of microbes and disease (Dawod, 2011). Therefore, it is necessary to improve simulation capabilities for flood estimation and develop a set of technologies and tools for an effective early warning system (Abuzied et al., 2016; Borga et al., 2011). The estimation depends on the hazard information in the flooded area, so it is necessary to know the level of potential flashflood hazards and pay attention to the factors causing the flood. Based on this description, this research will analyze the characteristics of flashflood and assess the potential level of danger in the Bt. Kuranji sub-watershed based on GIS and hydrodynamic modeling.

2. Method

This research was conducted through three stages, namely: first, the preparation stage to determine the research location and determine the data and tools needed. Second, the field stage is to collect primary data and secondary data. Third, the analysis phase consists of morphometric, hydrology, hydraulics, and analysis of the potential for flash flood hazards.

The location of the study to analyze the hazard of flashfloods potential is the Bt. Kuranji Sub-watershed where determined using DEM morphometric analysis through the HEC-GeoHMS tool in ArcGIS as at the preprocessing stage of the terrain before modeling.

Table 1. Hydrological Soil Type Classification

HSG	Description
A (Low runoff potential)	Soil with a high infiltration rate, even when completely moistened. Consists of a deep layer of gravel and gravel sand, and has a high water transmission rate (infiltration rate greater than 0.3 inches/hour)
B	Soil with moderate infiltration rate when completely moistened. Consists of slightly fine to coarse texture with a moderate water transmission rate (infiltration rate 0.15-0.30 inch/hour)
C	Soil with a slow infiltration rate when thoroughly moistened. Consists of soil with a slightly fine to fine texture and has a layer that inhibits the downward flow of water. (rate 0.05-0.15)
D (high runoff potential)	The infiltration rate is very slow when completely wetted. Consists of clay with high development potential, soil with a high permanent water table, soil with a claypan layer, or clay layer near the surface layer, and shallow soil over impervious material, the infiltration rate of 0.05 inch/hour.

The data and tools used in this research are primary data and secondary data. The primary data are river geometry measurement data from BWS Aquaman and cross-sectional data of the Kuranji River. Secondary data are rain data from 1978 to 2015, historical flash floods, RBI maps, geological maps, soil types maps, land use maps, DEM IFSAR, Quickbird images and Bing maps, discharge data, and CN values. The CN value is obtained by making a map of the SCS-CN distribution through CN_{Grid} analysis. The SCS-CN distribution map is an input for flash flood hydrograph modeling using HEC-HMS. The CN_{grid} was created using land-use data and USDA hydrological soil type classification data (USDA-SCS, 2016), as presented in Table 1.

Morphometric Analysis

Morphometric analysis is used to determine river flow and the Kuranji watershed area and its sub-watersheds using the HEC-GeoHMS device, the data required is the DEM IFSAR of the Kuranji watershed.

Hydrological Analysis

Several steps in the hydrological analysis are:

a. Calculating the MAP (Mean Area Precipitation) or regional rainfall value using the ***Thiessen Polygon Method*** (Harto & Dip, 1993) with ***equation a***.

$$\bar{p} = \frac{\sum(A_1 p_1 + A_2 p_2 + ..A_n p_n)}{\sum A_{tot}} \qquad \text{(a)}$$

Where, p: MAP, *An*: Area representing the station, Pn: rain per station, and A_{tot}: total area of each sub-watershed.

b. To calculate the planned rain, this process begins with an analysis of the frequency of rain using the ***analysis model of Djoko Luknanto*** to obtain the planned discharge for the return periods of 2, 5, 10, 20, 50, and 100 years. Next is to calculate the hourly rain distribution using the ***Mononobe Method*** (Triatmodjo, 2010) with ***equation b***.

$$I_t = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{\frac{2}{3}} \qquad \text{(b)}$$

Where, I_t: hourly rain intensity (mm/hour), t: Rain duration (Hours), R_{24}: maximum rainfall of 24 hours. Hourly rains are converted into the ***ABM (Alternating Block Method) Model*** to be used as input for the HEC-HMS device. Next, calculate the effective rain using ***CN***

Table 2. CN Composite Value by Hydrological Soil Type

Land Use	Hydrological soil type (HSG)			
	A	B	C	D
Open water	100	100	100	100
Growing open space	39	61	74	80
Developing area, low intensity	57	72	81	86
Medium intensity developing area	77	85	90	92
High intensity developing area	98	98	98	98
Barren land, rocks, sand, clay	63	77	85	88
deciduous forest	36	60	73	79
mixed forest	36	60	73	79
Shrubs	35	56	70	77
meadows, herbs	39	61	74	80
Grass, straw	49	69	79	84
Cultivated plants	67	78	85	89
Wetland/timber forest	36	60	73	79
Palusrine forest wetlands	49	69	79	84
Herb wetland	49	69	79	84

c. Hydrological modeling was carried out using the HEC-HMS device to produce a design flood discharge hydrograph for each return period and to determine the characteristics of the flashflood hydrograph. The hydrograph model used is ***the HSS SCS model***. Before modeling, the base flow for each sub-watershed in the upstream part is calculated using ***GAMA 1*** formula (Harto, 2000) with ***equation c***.

$$Q_B = 0{,}4715\, A^{0,6444} D^{0,943} \tag{c}$$

Where, Q_B= base flow (m^3/s), A = watershed area (Km^2), D = drainage network density (Km/Km^2). Baseflow characteristics were calculated using the ***exponential recession model*** (Feldman, 2000) in HEC-HMS with ***equation d***:

$$Q_t = Q_o k^t \tag{d}$$

Where, Q_t= baseflow discharge (m^3/s), Q_o= initial baseflow at zero time (m^3/s), k = recession ratio. The HEC-HMS modeling process begins with filling in the model components consisting of several model parameters. It is broadly described in Figure 1.

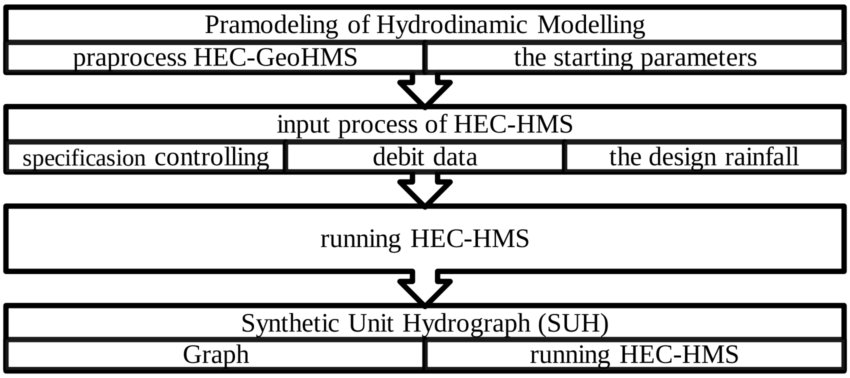


Figure 1. HEC-HMS Modelling Process

Hydraulic Analysis

Hydraulics analysis consists of pre-model analysis using HEC-GeoRAS tools on ArcGIS tools, and flood modeling using HEC-RAS tools. The hydraulics analysis aims to obtain a potential flash flood flow model for each return period, the area of the floodplain, the depth value, and the velocity of the flood flow. The input in the hydraulics analysis is the peak discharge value of the hydrograph from the HEC-HMS model, as well as the morphometric data from the pre-model analysis.

Flash Flood Hazard Potential Analysis

The analysis of the hazard potential in this study uses the value of the flood characteristics obtained from the hydraulics analysis. Determination of potential flood hazard is based on the value of depth and flow velocity for return periods of 2, 5, 10, 20, 50, and 100 years which are classified into high, medium, and low hazard levels. The formula for assessing the potential level of flashflood hazard using ***equation e***.

$$TBBB=[H1+H2] \tag{e}$$

Where, H1: Depth H2: Velocity

3. Result and Discussion

Morphometric Analysis

In this study, the research location is divided into two areas, namely: the upstream part of the sub-watershed as an area to analyze the characteristics of the flashflood hydrograph, and the middle to the downstream part to assess the potential for flash flood hazards. The upstream area of the Bt. Kuranji sub-watershed has a tributary consisting of Bt. Limau Manis with a length of 16.42 Km and a watershed area of 31.93 Km^2, as well as twin streams of Bt. Padang Janiah and Bt. Padang Karuah has a relatively parallel channel from upstream to its confluence, with a length of 18.86 Km and a watershed area of 82.26 Km^2. When it rains and if there is a flood, this twin flow will accumulate flooding with almost the same peak time. In the middle of the watershed, there is a tributary consisting of Bt. Air Sungkai with a length of 3.63 Km and a watershed area of ± 6 Km^2.

The results of morphometry processing of the watershed in the ArcGIS tool are imported into the HEC-HMS device to obtain the parameters for analyzing the characteristics of the flood hydrograph of the Bt. Kuranji sub-watershed. Details of the morphometry of each sub-watershed are presented in Table 3, while the study area is presented in Figure 2.

Table 3. Bt. Kuranji Sub-watershed Morphometry

Sub-watershed	Area (km2)	Main River (m)	Average River Slope (%)	Average Watershed Slope (%)
W210	8.05	2351.97	0.34	0.53
W250	20.66	2889,26	0.08	0.13
W260	18,10	7131.54	0.05	0.34
W290	21.48	5939.74	0.08	0.22
W350	32.38	14755.86	0.06	0.25
W360	6.65	1624.05	0.01	0.32
W380	12.89	6409.07	0.02	0.28

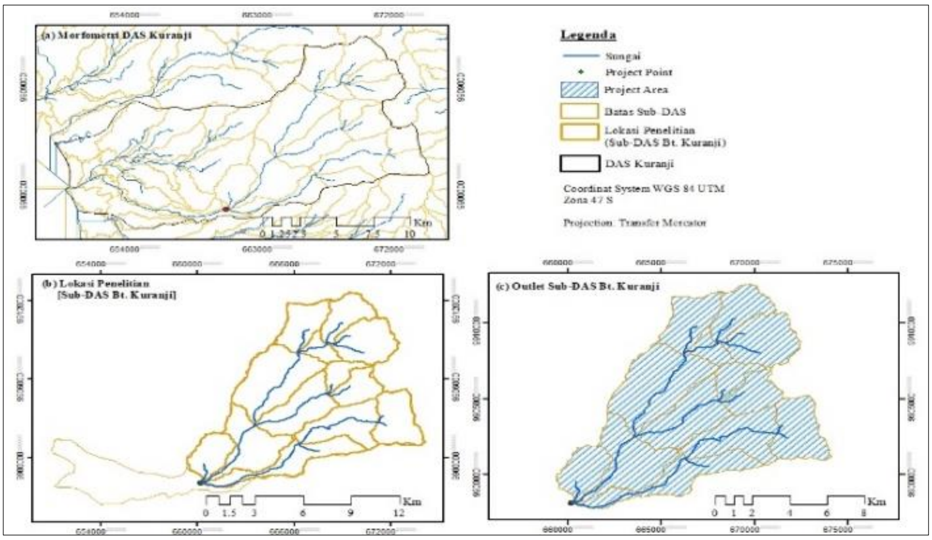


Figure 2. morphometric analysis

HMS scheme for flow tracking in the Bt. Kuranji Sub-watershed is divided into 4 flow elements starting from the upstream of the watershed to the outlet, namely with the codes R100, R160, R170, and R180. Each flow tracking element conveys water collected at the junction at each downstream of the sub-watershed to the outlet. In this research area, there are 4 flow intersections, namely with codes J57, J49, J52, and J60.

Hydrological Analysis

The hydrological analysis aims to obtain hourly rainfall data using daily rainfall data for a maximum of 38 years, namely data from the range 1978 to 2015 years that from 3 rain stations, including Sta. Gunung Nago, Sta. Padang Alai, and Sta. Batu Busuk. The rain data was converted into MAP rain for the W210, W250, W260, W290, W350, W360, and W380 sub-watersheds using *equation a*. The rainfall data for each sub-watershed was analyzed using *the Djoko Luknanto frequency analysis model*, and *the Mononobe model analysis* so that the hourly rainfall was obtained. The hourly distribution of design rainfall is presented in Table 4.

Table 4. Hourly Rainfall Distribution Based on ABM Model

Sub-watershed	Return Period	PT (mm)	Rain Distribution (mm)		
			1	2	3
W210	2	87.77	11.10	60.85	15.82
	5	121.06	15.30	83.94	21.82
	10	142.80	18.05	99.01	25.74
	20	163.43	20.66	113.31	29.45
	50	189.92	24.01	131.68	34.23
	100	209.73	26.51	145.42	37.80

W250	2	157.46	19.91	109.17	28.38
	5	226.36	28.62	156.95	40.79
	10	271.98	34.38	188.58	49.02
	20	315.73	39.92	218.92	56.90
	50	372.38	47.08	258.19	67.11
	100	414.82	52.44	287.62	74.76
W260	2	77.80	9.84	53.94	14.02
	5	98.43	12.44	68.25	17.74
	10	112.09	14.17	77.72	20.20
	20	125.19	15.83	86.80	22.56
	50	142.15	17.97	98.56	25.62
	100	154.85	19.58	107.37	27.91
W290	2	148.02	18.71	102.63	26.68
	5	212.74	26.89	147.50	38.34
	10	255.58	32.31	177.21	46.06
	20	296.68	37.51	205.71	53.47
	50	349.88	44.23	242.59	63.06
	100	389.75	49.27	270.24	70.24
W350	2	136.82	17.30	94.87	24.66
	5	196.53	24.84	136.26	35.42
	10	236.05	29.84	163.67	42.54
	20	273.97	34.64	189.96	49.37
	50	323.05	40.84	223.99	58.22
	100	359.83	45.49	249.49	64.85
W360	2	101.82	12.87	70.60	18.35
	5	132.71	16.78	92.02	23.92
	10	150.02	18.97	104.02	27.04
	20	164.72	20.82	114.21	29.69
	50	181.52	22.95	125.86	32.71
	100	192.77	24.37	133.66	34.74
W380	2	80.92	10.23	56.11	14.58
	5	100.99	12.77	70.03	18.20
	10	111.49	14.09	77.30	20.09
	20	120.15	15.19	83.31	21.65
	50	129.91	16.42	90.07	23.41
	100	136.41	17.25	94.58	24.58

Hydrograph Characteristics of Flash Flood in Bt. Kuranji Sub-watershed

- *Baseflow (Qb)*

Baseflow is the relationship between the area of the watershed (A) and the drainage conditions of the watershed and it is a continuous runoff that has a certain peak discharge when it rains and is an accumulation of flow before the flood that affects when a flood occurs. Baseflow calculation (*Qb*) in the Bt. Kuranji sub-watershed uses *the GAMA I Method* with parameters in Table 5.

Table 5. Bt. Kuranji Sub-Basin Flow

watershed	Area (Km^2)	Total River Length (Km)	Watershed Drainage (Km/Km^2)	Base Flow (m^3/s)
W250	20.66	8.84	0.428	1.49
W210	8.05	2.35	0.292	0.57
W290	21.48	8.73	0.406	1.46
W260	18,10	7.13	0.394	1.27
W360	6.65	1.62	0.244	0.42
W350	32.38	17.90	0.553	2.53
W380	12.89	6.41	0.497	1.27

- *HEC-HMS Simulation*

This research uses the synthetic unit hydrograph SCS method (SUH-SCS) to obtain the flood hydrograph characteristics of the Bt. Kuranji sub-watershed. SUH-SCS is a dimensionless watershed calculation method that has a single peak discharge. The SUH-SCS model is known as SCS-CN, because the parameter determination uses the CN (*Curve Number*) value obtained from the relationship between watershed hydrological conditions, soil types, and land use in the studied watershed. The SUH-SCS parameters in the HEC-HMS model are presented in Table 6.

Table 6. SUH-SCS Parameters in the HEC-HMS Model

Model	**Description**	**SCS-CN. Parameters**		**Bt. Kuranji sub-watershed**
		Min	**Max**	
SCS Loss	*He*	0 mm	500mm	Calculation of morphometry and CN
	CN	1	100	
SCS UH	*lag time*	0.1 min	30000 min	Tc count
Baseflow	*Initial baseflow*	0 m^3/s	100000 m3/s	The basic flow of the Gamma I . method
	Recession constant	0.00001	1	
	Flow to peak ratio	0	1	
Muskingum Routing	*K*	0.1 hour	150 hours	2 hours
	X	0	0.5	0.5
	Number of sub reach	1	100	morphometric scheme
time-series	*Precipitation gage*			MAP of each sub-watershed

In the HEC-HMS model, the simulation stages are carried out sequentially. Starting from the input element that becomes the SUH-SCS parameter to *the Loss Method* calculation using the *SCS model*, then the output is the difference in rain which is entered into the *Transform Method* calculation using the SCS UH model. The results of the Transform Method are *direct flow* and *baseflow*, where baseflow is added with the Baseflow Method using a recession model so that the outlet discharge of each sub-watershed is obtained. Finally, the routing process is carried out using the Routing Method namely *the Muskingum Model*, so that the amount of discharge at the main outlet of the Bt. Kuranji Sub-watershed is obtained. The flow tracing input obtained from the morphometric analysis in ArcGIS is presented in Table 7.

The input process is carried out in several iterations based on return periods of 2, 5, 10, 20, 50, and 100 years by changing the time-series data according to the distribution of rain for each return period. The input process is presented in figure 3.

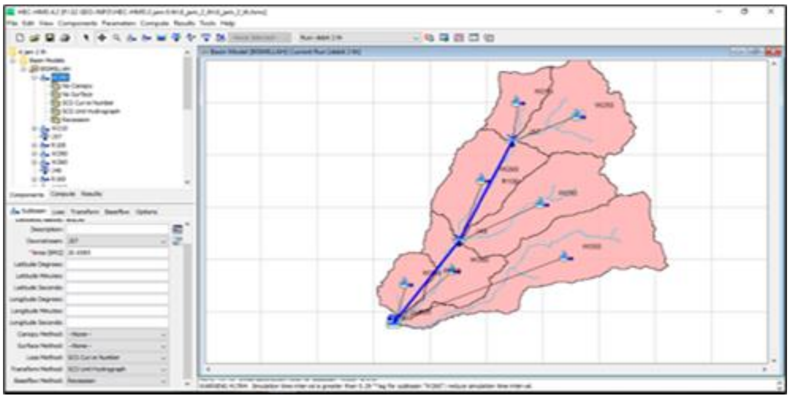


Figure 3. HEC-HMS Parameter Input Process

Table 7. Muskingum Method Flow Tracing Parameters

cut off	Length (m)	V m/s	K
R100	6095,495	3.23	2
R160	5418,744	1.81	2
R170	97,995	2.25	1
R180	24,929	2.25	1

- *Flash Flood Hydrograph Characteristics*

The SCS method is used to determine the discharge hydrograph causing flashflood in the upstream part of the Bt. Kuranji Sub-watershed on return periods of 2, 5, 10, 20, 50, and 100 years. The simulation results show that the Bt. Kuranji sub-watershed has a slim shape of SUH-SCS and sharp approaching its peak. This means that rain for 3 hours only takes a short time to accumulate into flood flow, and will return to normal flow in a short time as well. In general, the results of the SUH-SCS simulation in Table 8 show the potential for flash floods in the Bt. Kuranji Sub-watershed, because one of the characteristics of a flash flood is the shape of the discharge hydrograph which is slim and sharp at its peak (Pedzisai, 2010).

Based on the SCS hydrograph, it is known that from 3 hours of rain, an initial flow of 9 m^3/sec occurs. During the 3-hour rain duration, there is a possibility of one or more repetitions of the peak discharge of 168.4 m^3/s in 2 years. The discharge is designed to be repeated or to occur 50 times within 100 years. Meanwhile, within 100 years there will be one or more repetitions of peak discharge of 724.9 m^3/s.

The peak discharge of 168.4 m^3/s can cause an increase in the volume of the Bt. Kuranji Sub-watershed is 61.91 mm, and the same repetition will occur once or more within 2 years. The same volume is also designed to be repeated at least 50 times within 100 years. Meanwhile, within 100 years, it is designed that there will be one or more repetitions of the flow volume of 289.51 mm, which comes from a discharge of 724.9 m^3/s. This event applies to each return period and is followed by the peak discharge and the resulting volume.

Table 8. Flash Flood Potential Discharge in the Bt. Kuranji Sub-watershed

t (hour)	**Flood Discharge Based on T (Return Period) (m3/s)**					
	Q 2 y	**Q 5 y**	**Q 10 y**	**Q 20 y**	**Q 50 y**	**Q 100 y**
12:30	9	9	9	9	9	9
13:30	9	9	9	9	9	9
14:30	9	9	9	9	9	9
15:30	20.1	23.9	26.2	28.3	31	32.9
16:30	96	147.5	185.8	224.7	277.8	319.2
17:30	168.4	287.9	381.5	479.6	616.4	724.9
18:30	152.8	264	350	439.6	563.5	661.1
19:30	120.5	205.9	273.9	346	447.2	528
20:30	97.6	173.8	237	305.2	402.5	480.9
21:30	77.1	144.7	202.1	264.6	354.2	426.6
22:30	58.2	113.6	161.2	213.1	287.8	348.4
23:30	44.2	87.5	124.9	165.8	224.8	272.8
00:30	34.6	68	96.8	128.5	174.4	211.8
01:30	28.4	54.6	77.1	102	138.2	167.8
02:30	24.6	45.8	64	84.3	113.9	138.1
03:30	22.3	40.3	55.7	73	98.4	119.1
04:30	20.9	37	50.6	66.1	88.7	107.3
05:30	20.1	35	47.5	61.8	82.9	100.1
06:30	19.7	33.8	45.7	59.3	79.4	95.8
07:30	19.4	33.1	44.6	57.9	77.4	93.3
08:30	19.2	32.7	44	57	76.2	91.9
09:30	19.2	32.4	43.7	56.5	75.5	91
10:30	19.1	32.3	43.5	56.3	75.1	90.6
11:30	19.1	32.2	43.4	56.1	74.9	90.3
12:30	19.1	32.2	43.3	56	74.8	90.1
13:30	19.1	32.2	43.3	56	74.7	90.1
max	168.4	287.9	381.5	479.6	616.4	724.9

The SUH-SCS hydrograph for each return period is presented in figure 4, while the change in peak discharge and volume produced each return period can be seen from the linear line presented in figure 5.

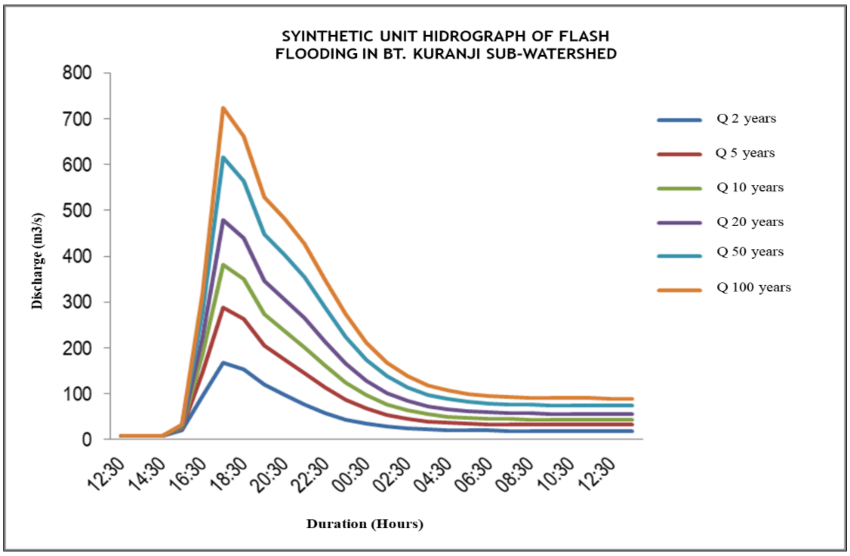
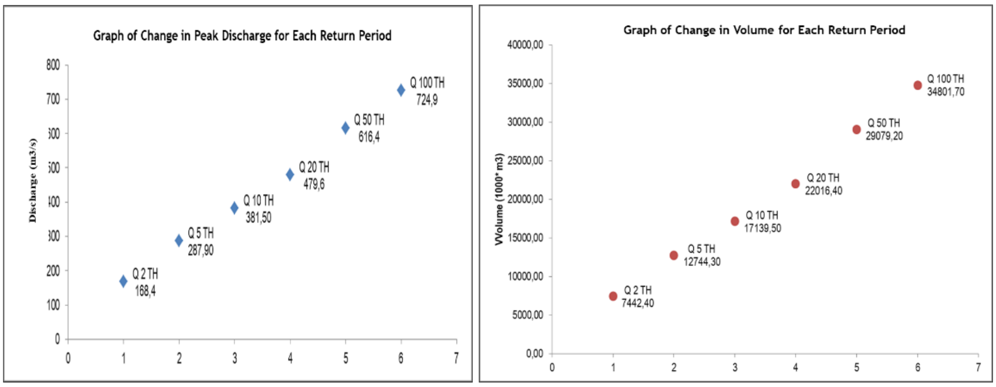


Figure 4. Hydrograph of Flood Discharge Potential of the Bt. Kuranji Sub-watershed



(a) (b)

Figure 5. (a) Graph of Change in Peak Discharge for Each Return Period and (b) Graph of Change in Volume of Each Return Period

Hydraulic Analysis with HEC-RAS

The hydraulics modeling was carried out in the middle to downstream areas of the Bt. Kuranji Sub-watershed with an area of 2,068 Ha or 21 Km^2. The hydraulics modeling begins by filling in the input data such as geometry data, downstream boundary conditions, and the data of upstream boundary conditions on HEC-RAS. Geometry data was obtained from the results of the IFSAR DEM terrain preprocessing using the HEC-GeoRAS tools, while the downstream boundary condition data was the normal depth data for the downstream, and the upstream boundary condition data was the peak discharge of the SCS hydrograph for each return period obtained from the HEC-HMS simulation. The flash flood modeling in the Bt. Kuranji sub-watershed for each return period has resulted the area of flood plain that accompanied by the value of the depth flood (Depth), the value of the velocity of the flood flow (Velocity), and the value of the height of the floodwater level (Water Surface Elevation) which is displayed in Figure 6 to 8. The area of flood inundation as the simulation results is presented in Table 9.

Table 9. The Flood Inundation Area for Each Return Period

Return Period (Years)	Flood Inundation Area (Ha)	Flooded Research Area (%)
2	108.26	5.24
5	197.42	9.55
10	268.97	13.01
20	348.82	16.87
50	448.94	21.71
100	490.12	23.70

Based on Table 9 can be seen the percentage of the research area or storage area that was hit by floods. The largest flood-affected area was caused by 100 years of flooding, with an area of 490.12 hectares or 24% of the storage area. Meanwhile, the smallest flood-affected area is in the 5-year return period, which is 108.26 ha or 5.42% of the storage area. The results of the modeling state that the greater the flood discharge value, the higher the potential for flood-affected areas.

Previous studies related to flood modeling with HEC-RAS used return periods of 10, 25, and 50 years to obtain flood area and depth parameters for spatial planning (Istiarto & Wibowo, 2007), while Afrianto (2015) carried out flood reconstructions that had occurred to obtain flood area in assessing the condition of the embankment in the West Jakarta Flood Canal. Using the different return periods and time parameters in flood modeling is carried out with the consideration that different watersheds or locations have different flood characteristics. On the other hand, using time parameters is also limited by the purpose of the flood modeling itself. In the analysis of the potential flash flood hazard in the Bt. Kuranji sub-watershed, the researcher chose to do modeling with a return period of 2, 5, 10, 20, 50, and 100 years to look at fluctuations in potential floods that occur in the study area. The return period of 100 years is considered sufficient time to obtain the potential for flash floods from the availability of 38 years of rain data.

The modeling results show that flashflood in the study area for 2 years return period to 100 years return period has a flow velocity between 0.01 m/s to 76.07 m/s. The value of the flow velocity for the return period of 2 years is 0.01 m/s to 32.11 m/s. The 5-year return period flow velocity values are 0.01 m/s to 34.93 m/s. The value of the flow velocity for the 10 years return period is 0.01 m/s to 45.43 m/s. The flow velocity values for the 20 years return period are 0.01 m/s to 55.37 m/s. The flow velocity values for the 50 years return period are 0.01 m/s to 67.67 m/s, and the flow velocity values for the 100 year return period are 0.01 m/s to 76.07 m/s. The modeling shows that the height of the inundation generated by the flood is directly proportional to the velocity of the flow.

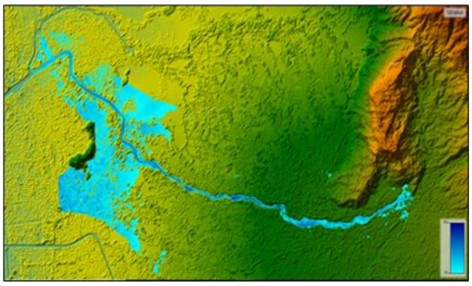


Figure 6. Flood Depth Modeling Results for 100-year Return Period

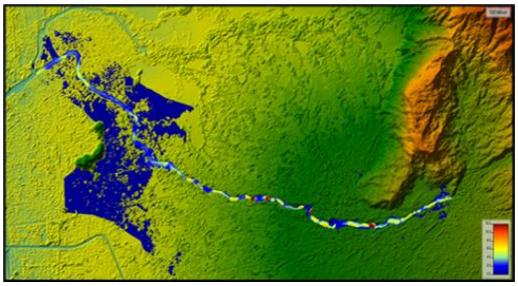


Figure 7. Flood Velocity Modeling Results for 100-year Return Period

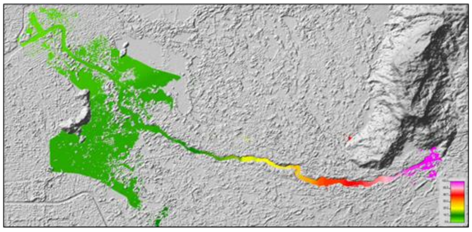


Figure 8. Flood Water level Modeling Results for 100-year Return Period

Flash Flood Hazard Potential Analysis

- *Flash Flood Distribution Mapping*

The results of the hydraulics analysis were then overlaid with administrative data of the research area to obtain information on the flash flood distribution of Bt. Kuranji. in each area. The extent of flood distribution in each affected village based on flooding that occurred in the return periods of 2, 5, 10, 20, 50, and 100 years is presented in Table 10. Spatially, differences in inundation areas due to the smallest flood discharge or return period of 2 years up to the largest flood discharge or return period of 100year presented in Figures 9 to 14.

Table 10. Distribution Of Flooded Area

No	Village	Flooded area (Ha) per return period					
		2 y	5 y	10 y	20 y	50 y	100 y
1	Kalumbuk	2,27	2,83	7,02	13,86	24,13	27,53
2	Tabing Banjar Gadang	3,83	16,55	29,20	39,65	48,85	50,99
3	Ampang Kuranji	0,49	8,51	19,49	32,86	45,58	49,12
4	Pasar Ambacang	6,73	7,71	8,39	9,09	9,84	10,43
5	Lubuk Lintah	4,74	5,85	6,76	9,47	14,69	15,75
6	Korong Gadang	6,61	7,73	8,19	8,82	9,65	10,56
7	Kuranji	5,60	7,85	9,40	10,36	10,97	11,37
8	Anduring	-	0,08	0,72	3,70	9,41	12,44
9	Gunung Sarik	-	-	-	-	-	0,02
10	Surau Gadang	7,78	13,78	19,23	26,35	36,70	43,54
11	Parak Laweh	10,47	21,65	29,06	40,51	59,90	67,71
12	Kampung Olo	16,48	27,44	32,68	38,39	45,13	49,82
13	Kampung Lapai	0,60	0,73	0,91	1,21	2,40	3,30
14	Kurao Pagang	5,76	9,57	12,90	15,54	18,82	21,05
15	Gunung Pangilun	14,37	25,01	30,48	34,14	36,76	37,26
16	Alai Parak Kopi	10,68	27,52	37,72	45,11	51,02	52,09
17	Kapalo Koto	2,61	3,36	4,18	5,18	6,54	7,70
18	Kampung Dalam	0,89	1,07	1,19	1,37	1,58	1,74
19	Cupak Tangah	3,32	3,91	4,26	4,92	6,31	6,63
20	Lambung Bukit	4,45	5,22	5,85	6,63	8,64	8,86

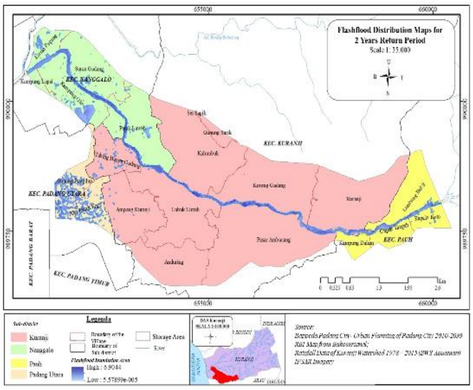


Figure 9. Flash Flood Distribution 2 year return period

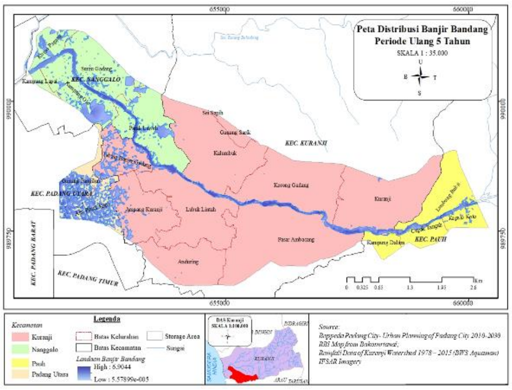


Figure 10. Flash Flood Distribution 5 year return period

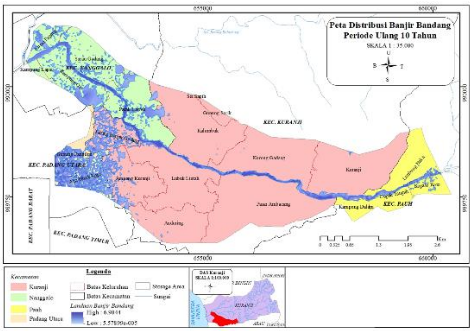


Figure 11. Flash Flood Distribution 10 year return period

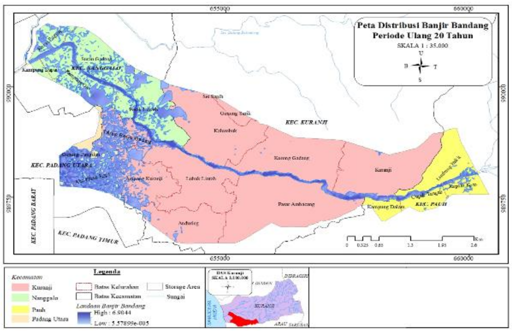


Figure 12. Flash Flood Distribution 20 year return period

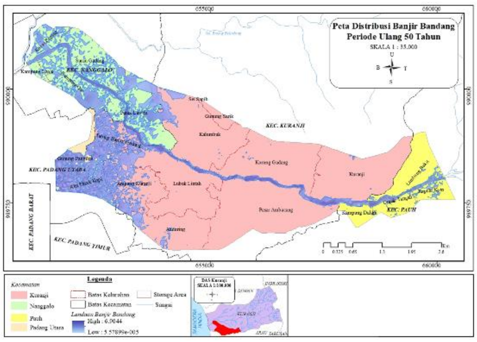


Figure 13. Flash Flood Distribution 50 year return period

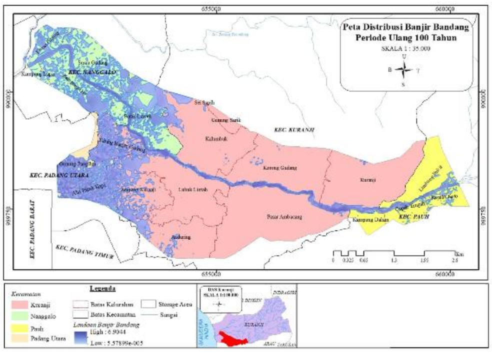


Figure 14. Flash Flood Distribution 100 year return period

- *Model Calibration Results*

The calibration process in this study is to compare the simulation results with data from the 2012 Flashflood Location Map which has been validated by the Padang City BPBD. The model calibration results are presented in Table 11. The model calibration process shows that the simulated flood area has fairly good suitability compared to the flash flood area in July 2012.

Table 11. flashflood calibration results

No	Simulation Results	Flashflood hazards on 2012	accuracy
	village	village	
	dist. Kuranji		
1	Gunung Sarik	Gunung Sarik	√
2	Kalumbuk	Kalumbuk	√
3	Tabing Banjar Gadang	Tabing Banjar Gadang	√
4	Ampang Kuranji	Ampang Kuranji	√
5	Anduring	Anduring	√
6	Pasar Ambacang	Pasar Ambacang	√
7	Lubuk Lintah	Lubuk Lintah	√
8	Korong Gadang	Korong Gadang	√
9	Kuranji	Kuranji	√
	Dist. Nanggalo		
10	Surau Gadang	Surau Gadang	√
11	Parak Laweh	Parak Laweh	√
12	Kampung Olo	Kampung Olo	√
13	Kampung Lapai	-	-
14	Kurao Pagang	Kurao Pagang	√
	Dist. Pauh		
15	Kapalo Koto	Kapalo Koto	√
16	Kampung Dalam	Kampung Dalam	√
17	Cupak Tangah	Cupak Tangah	√
18	Lambung Bukit	Lambung Bukit	√
	Dist. Padang Utara		
19	Gunung Pangilun	-	-
20	Alai Parak Kopi	-	-

The model is very good at simulating flooding starting from the discharge collected from each flow meeting to the inundated area downstream. The distribution of the simulated flood in the downstream area is higher than the actual flood that occurred. This is influenced because the HEC-RAS model used to simulate runoff is a one-dimensional model, where the water level elevation is calculated only once for each cross section, therefore the water level elevation in the simulation does not vary along the cross section of the flow. In contrast to the reality, the water level elevation in inundation along the river side (overbank) is usually higher than the main channel.

The difference in water level elevation in the generated model with the elevation of the actual condition also affects the condition of water that accumulates in the downstream area. In addition, the resolution of the DEM (Digital Elevation Model) also affects the quality of flood predictions from HEC-RAS. The higher resolution of the DEM, the more sensitive the cross section to hydrological changes that occur (Cook, 2008). In this study, high resolution DEM was used so that its sensitivity to hydrological changes was also quite good.

The results of the comparison of the model with the facts show that the incidence of flashflood in 2012 is included in the flood area in the modeling results. The flash flood in 2012 did not reach the most downstream area of the Bt. Kuranji River is the North Padang District. However, the modeling results show that there is a potential for flashflood that reaches 2 villages in North Padang District and 1 village in Nanggalo District. The villages are Gunung Pangilun Village, Alai Parak Kopi Village, and Kampung Lapai Village.

The results of the analysis of the suitability of the HEC-RAS model obtained an accuracy of 74% (Horritt & Bates, 2002). This shows that the model results can describe the actual condition of 74%, based on this accuracy the HEC-RAS model can be used to analyze the distribution, depth, and duration of floods for a predetermined return period and predict the potential for future floods with that return period.

- *Mapping of Potential Flash Flood Hazards*

The analysis of the potential for flash flood hazards is carried out from the results of modeling with HEC-RAS using the parameters of depth and flow velocity. The flood hazard parameters are the recommended parameters for preparing a flood emergency action plan. The potential hazard in each return period is determined based on the level of hazard which is classified into three classes, namely low, medium, and high hazard classes using equation e. The depth classes are low (<1m), medium (1m to 1.5m), and high (>1.5m). The flow velocity levels are low (<0.5 m/s), medium (0.5-1 m/s), and high (>1 m/s).

Creating the flashflood hazard map refers to the analysis of the parameters of the flood depth and flood flow velocity for a return period of 2 years to 100 years. The assessment and classification of flood hazards can be seen in Table 12. Based on the hazard assessment criteria, the hazard classes are categorized into low hazard class (score 1 to 1.66), medium hazard (score 1.67 to 2.33), and high hazard (scores 2.43 to 3).

Table 12. Flash Flood Hazard Assessment.

Flow Speed	**Depth**		
	Low (< 1m)	**Medium (1-1.5m)**	**Height (> 1.5 m)**
Low (<0.5m/s)	1	1.5	2
Medium (0.5 - 1 m/s)	1.5	2	2.5
Height (>1 m/s)	2	2.5	3

The results of the analysis of the level of flashflood hazard due to maximum flood discharge in the return periods of 2, 5, 10, 20, 50, and 100 years are shown in Figures 16 to 21. Based on this figure, it is known that the high hazard in each return period is distributed in the area along the channel. rivers, and the closer to the land or towards settlements the level of danger is also lower. Areas with the least hazard caused by flooding in the 2 year rain return period. while the area with the greatest danger is caused by flooding in the 100 year return period.

The area affected by flashflood in the 2-year return period is based on the level of danger, namely: high hazard with an area of 26 Ha, medium hazard with an area of 27.96 Ha, and low hazard with an area of 52.88 Ha. The area affected by flashflood in the 100-year return period is based on the level of danger, namely: high hazard with an area of 40.59 ha, medium hazard with an area of 256.07 ha, and low hazard with an area of 188.70 ha.

The results of the flood modeling show that the flood discharge in the 2 year return period caused flash floods that hit 18 sub-districts in the district of Kuranji, Nanggalo, North Padang, and Pauh. The floodplain continues to increase along with the increase in flood discharge as the results of flash flood modeling for the 100-year return period that hit 20 villages that distributed in the district of Kuranji, Nanggalo. North Padang, and Pauh. According to hazard analysis, it is known that the most extensive area with a high hazard class and a medium hazard class due to a 2-year return period is Parak Laweh Village. The modeling results show that the greatest potential for flooding is in the 100-year return period. Hazard analysis in the 100-year return period shows that Parak Laweh Village is also the largest flood area, but most of the area belongs to the low hazard class. The most extensive area with a high potential for danger during a 100 year return period flood is Korong Gadang Village.

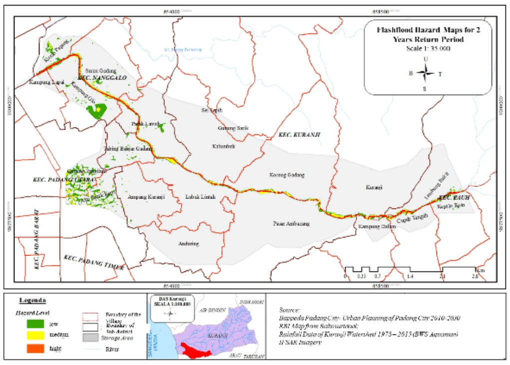


Figure 16. Flash Flood Hazard Map for 2 Years Return Period.

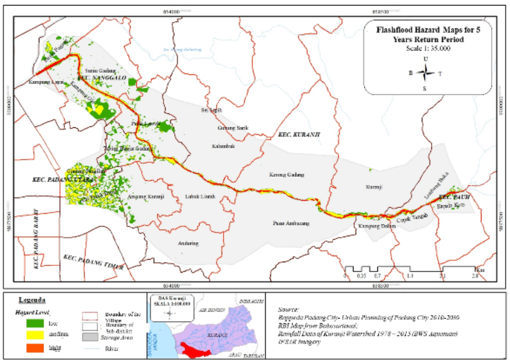


Figure 17. Flash Flood Hazard Map for 5 Years Return Period.

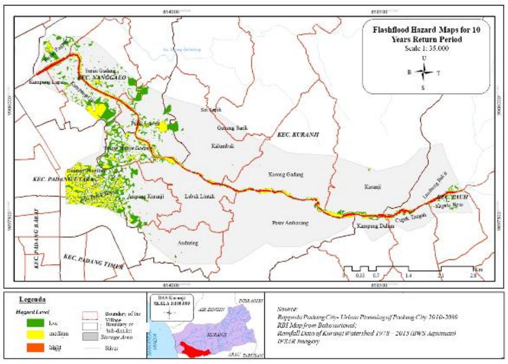


Figure 18. Flash Flood Hazard Map for 10 Years Return Period.

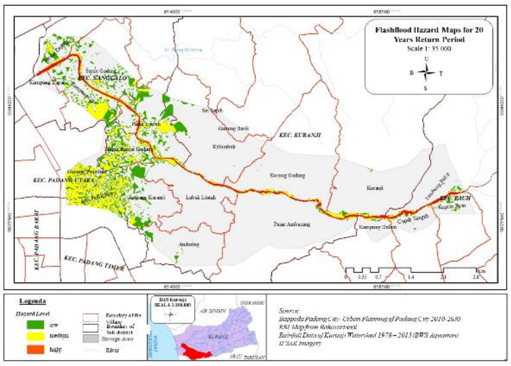


Figure 19. Flash Flood Hazard Map for 20 Years Return Period.

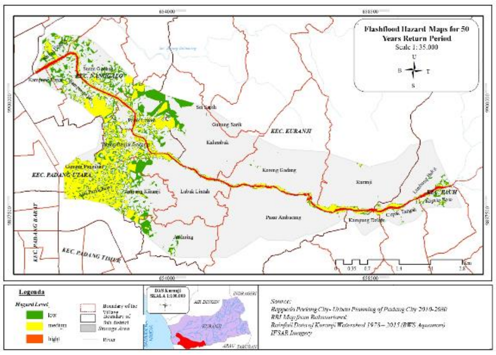


Figure 20. Flash Flood Hazard Map for 50 Years Return Period.

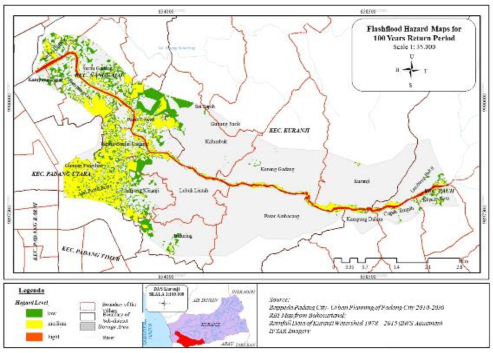


Figure 21. Flash Flood Hazard Map for 100 Years Return Period.

4. Conclusion

Flash Flood Hydrograph Characteristics of Bt. Kuranji Sub-watershed from rainfall 38 years shows the concentration time (Tc) of rain that causes flooding is 3 hours. The peak of effective rain (Pe) occurs at the 2nd hour to the 3rd hour. The hydrograph shows that Q 2 years is 168.4 m3/s, Q 5 years is 287.9 m3/s, Q 10 years is 381.5 m3/s, Q 20 years is 479.6 m3/s, Q 50 years is 616.4 m3/s, and Q 100 years is 724.9 m3/s. The SCS Hydrograph of Bt. Kuranji River are slender and sharp nearing the peak, thus meaning that 3 hours of rain only takes a short time to accumulate become a flood flow, and will return to normal flow in no time as well. This shows one of the characteristics of flashflood that occurs quickly in a relatively short time.

Analysis of the potential level of flashflood hazards in the Bt. Kuranji sub-watershed in return period of 2, 5, 10, 20, 50, and 100 years based on the parameters of depth level and flow velocity level indicates that the occurrence of flashflood has the potential to hit 4 sub-districts, namely Kuranji, Nanggalo, North Padang, and Pauh. The least flooded area is caused by a 2-year return period flood discharge, with an area of 106.44 Ha, inundating 18 sub-districts where 24.33% of the area is categorized as high hazard potential, while 26.17% is categorized as moderate hazard and 49, 50% categorized as low hazard. The most extensive flood area is caused by flood discharge for a return period of 100 years, with an area of 485.36 hectares which inundated 20 urban villages. The category of high hazard potential is 8.36%, the medium hazard category is 52,76% and the low hazard category is 33.88%. The most extensive area with a high potential for danger during a 100 year return period flood is Korong Gadang Village.

5. Conflict of Interest

There are no conflicts to declare.

6. Official Statement

Thanks are expressed to BWS Aquaman from the Water Resources Management Office of West Sumatra Province and the Indonesian Geospatial Information Agency for providing supporting data for this research.

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